

**THE POTENTIAL FOR TIME-OF-USE PRICING IN
INDIAN ELECTRIC UTILITIES**

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ABSTRACT

Time-of-use (TOU) pricing (or peak load pricing, as it is more widely known) has been extensively applied in recent years in several countries, and a wealth of experience is now available. While occasional and hesitant forays have been made into this field by some Indian utilities, a significant or systematic effort yet remains to be made. It is the purpose of this paper to evaluate the potential for time-of-use pricing in India.

Key Words: Electric Utilities, Energy Pricing, Time-of-Use, India.

BRIEF REVIEW OF THEORETICAL BACKGROUND

Time-of-use pricing is a corollary of marginal cost pricing, and a recognition of the fact that marginal costs of supply in an electric utility system, vary significantly by time of the day as well as by season. The economic arguments for a pricing system based on marginal costs, calculated separately for different categories of consumers and at different voltages, have been discussed in detail in the literature^a(1)& (2). The non-storable nature of electricity, taken together with the varying demands by time of the day, lead to these differing marginal costs for different hours of the daily cycle.

A simplified illustration used by Boiteaux, considers a load curve broken into six independent levels (see figure below).

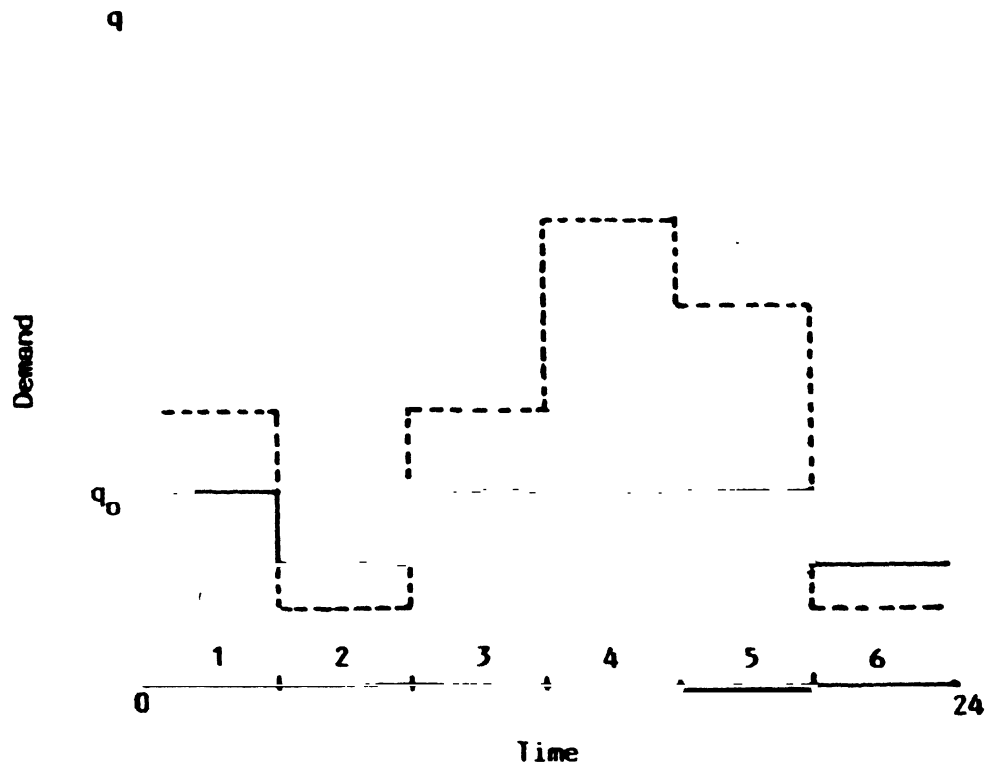


Fig. 1: Load curve - before and after introducing peak load pricing

The basic principles of peak load pricing may be illustrated with reference to the above simple framework. The objective of separate prices at every level is to bring the load curve to follow a horizontal line. If, however, we have to lower prices below energy cost (what Boiteaux calls 'partial cost') for any off-peak levels, in order to bring demand to a horizontal line,

the tariff would not be reduced below energy cost, but the load curve will be allowed to fall below the horizontal line for the off-peak periods. In the above example, off-peak periods 2 and 6 bear energy costs only, and periods marked 1, 3, 4 and 5, are brought down to the level of the horizontal line by a suitable charge for each period to meet the capacity cost of the plant. Horizontality of the load curve is achieved by the combined action of direct pressure of the price differences in the different periods, and the 'stretching' effect on the load curve, resulting from interchangeability of energy consumption, part of which moves from relatively expensive to cheaper periods (i.e. from peak to offpeak hours).

It is clear from the above that the time-uniform price represented by the dotted load curve in Figure 1, is higher than the energy cost during periods 2 and 6, and lower during the remaining periods 1, 3, 4 and 5. While the price is reduced in periods 2 & 6 to equal energy costs, it has to be increased above energy costs in periods 1, 3, 4 and 5. This is done by adding to it a suitable additional charge (separately for each period) to achieve horizontality of the load curve.

The additional charge levied in periods 1, 3, 4 and 5, is justified on the basis of the concept of "investment responsibility". The investment responsibility of the demand in any period, is equal to

the proportion of the capacity costs which must be charged in that period in order to achieve the optimum horizontal level (3).

POTENTIAL PEAK

Marginal cost theory is essentially a "forward-looking" approach, and it needs to be emphasised here that the relevant marginal cost is based on what the load curves would be after the tariff has changed the consumers' behaviour e.g., in the simplified model, the continuous load curve will be the basis of the marginal cost, and not the dotted load curve. It is, therefore, worth pointing out that the relevant peak for peak-load pricing is not the actual peak as reflected in the present load curves, but the 'potential' peak.

The favourable treatment given to off-peak consumption (by way of a lower price) and the peak capacity charge imposed on peak users, are often justified on economic grounds as follows. There is a causal relationship between peak use and the resultant capacity cost imposed on the utility (as well as the economy), whereas such a causal relationship does not exist in respect of off-peak use. Apart from its being unfair to levy capacity costs on offpeak users, the levy of such a charge would reduce off-peak consumption, and some capacity rendered **idle during** offpeak periods.(4)

EXPERIENCES OF TIME-OF-USE PRICING IN OTHER COUNTRIES

Theoretically speaking, peak-load pricing can be applied to all consumer categories. Consideration of the costs of metering, billing etc., has resulted in application of this principle mainly to high voltage industrial consumers.

France

France was the first electric utility in the world to introduce (in 1956) a marginal cost-based tariff, which has been progressively modified and expanded into what is currently the most sophisticated tariff structure. Peak load pricing was first applied to high voltage industrial consumers. There were five different daily rates applicable to each of the voltage levels. Three of these related to the winter months, and two to summer, loads in winter being generally higher. The highest rate was during three evening peak hours in winter; the next highest was during the day-time hours, designated as "full-use hours". The lowest rate was leviable during the off-peak (night) hours. In the summer months, there were no peak hour rates, but only two rates covering full use hours and off-peak hours - the summer rates generally being lower than the winter rates. The price differential between peak and off-peak, was about 4 to 1. EdF reported that the national load curve had flattened at the peak to the extent of nearly 5 per cent after a year of this pricing system.

The total resultant saving in capacity and energy costs at all levels was estimated at more than 50 billion francs for the seven years following the new tariff (5) (6). A recent paper contains a detailed discussion of the response of the EDF to the changing energy supply and demand situation in France (7). On the supply side, the share of oil has declined, and nuclear power has acquired a predominant position in the new optimal investment plan. On the demand side, seasonality of electricity use has sharpened, attributed by EDF mainly to changes in the pattern of working hours in recent years. The shape of the yearly load curve has deteriorated, though the daily load curve has become flatter. "There is a transition ... from a peak of a few hours a day during a good many days a year, to a system whose peak corresponds to a large number of hours the same day, but only during a few days a year, but at dates which cannot be foreseen" (7). The modified tariff system has taken into account the changes in the nature of the peak problem by including in the tariff a "peak day withdrawal option". The consumers on this optional tariff are effectively given an interruptible supply in exchange for a sizable reduction in electricity rates. The important difference in the case of this option is that the peak is mobile, and the consumers will be notified in real time by EdF when the mobile peak is about to commence.

U.S. Experience

The system of tariff revision in U.S. utilities, involving hearings before state regulatory commissions, has always emphasised actual costs and rates of return on capital investments. However, many U.S. utilities have recently shown an interest in peak-load pricing structures based on LRMC. Some of these utilities have also conducted peak-load pricing studies, which are available in reports and other publications. A Rand Corporation report has discussed some of the earlier studies(8). Estimates have been made of the nation-wide effects of a hypothetical six-hour peak-load rate on industrial consumption, with incentives similar to those included in the TOU rates in France and U.K. The range of potential reductions in peak-period consumption is given in the Table 1.

It will be several years before US customers have had sufficient time to take TOU rates fully into account in designing manufacturing equipment and planning production processes. At that time, the percentage reductions in peak-loads in the United States, may approach those observed abroad (9).

Many utilities in the U.S. are currently involved in peak load pricing experiments in which load research data are being continuously collected to enable design of effective time-of-day rates. A study in Connecticut

Light and Power Company shows that the on-peak percentage has fallen by nearly 1 per cent during the period 1983-86 for the industrial customers. It is also reported that on-going research for large industrial and commercial consumers, has helped the company in establishing effective new rate schedules and in evaluating the present and future effects of these rate schedules (10).

Korean Experience

Korea is one developing country which has recently tried to implement peak-load pricing in the industrial sector. It was important for Korea Electric Power Corporation (KEPCO) not only to know the load pattern, but also to undertake the more difficult task of estimating the likely consumer response to the peak load tariffs. KEPCO had to make the required demand forecasts, and decide on the appropriate price-levels in different pricing periods based on their marginal capacity and energy cost estimates. KEPCO as well as the Korean Chamber of Commerce and Industry, conducted independent surveys in order to analyse possible consumer response to the proposed peak load tariffs. On the basis of the sample surveys in the industrial sector, they estimated that the load curves could be flattened at the peak by at about 15 per cent, by appropriate peak load pricing. KEPCO used an 18-month

Table 1: Summary of Estimated Reductions in Load at Peak-Price Hours

Utility	Estimating Method	Type of Data	Percent Reduction in System Load	Percent Reduction in TOU Class Load	
			KW	KW	KWh
Long-term Change					
EdF (France)	Evolution of load	System load	14		
EdF	Individual customer load shapes	Subscribed demand		12.14	
C.E.G.B. (British)	Evolution of load	System load	13		
EdF/United States	Individual customer load shapes	Manufacturing customers		14.25	14.25
Intermediate-term Change					
EdF	Trends in hourly load	System load	5		
C.E.G.B.	Individual customer load shapes	Load management customers		40	
Short-term Change					
Pacific Gas & Electric	Evolution of load curve	TOU class		1.3-2.0	
Southern Cali- fornia Edison	Evolution of load curve	TOU class		0.6-1.6	0.7-1.2
San Diego Gas & Electric	Evolution of load curve	TOU class		3.5	5.6
Wisconsin Power and Light	Customer Survey	Reported scheduling & Equipment Changes		10	
Wisconsin Power and Light	Evolution of load curve	TOU class			9.7

Note: EdF = Electricity de France. C.E.G.B. = Central Electricity
Generating Board

preparatory period to explain the new tariffs to prospective consumers. The enforcement of the peak load tariffs had an encouraging response as shown in Figure 2.

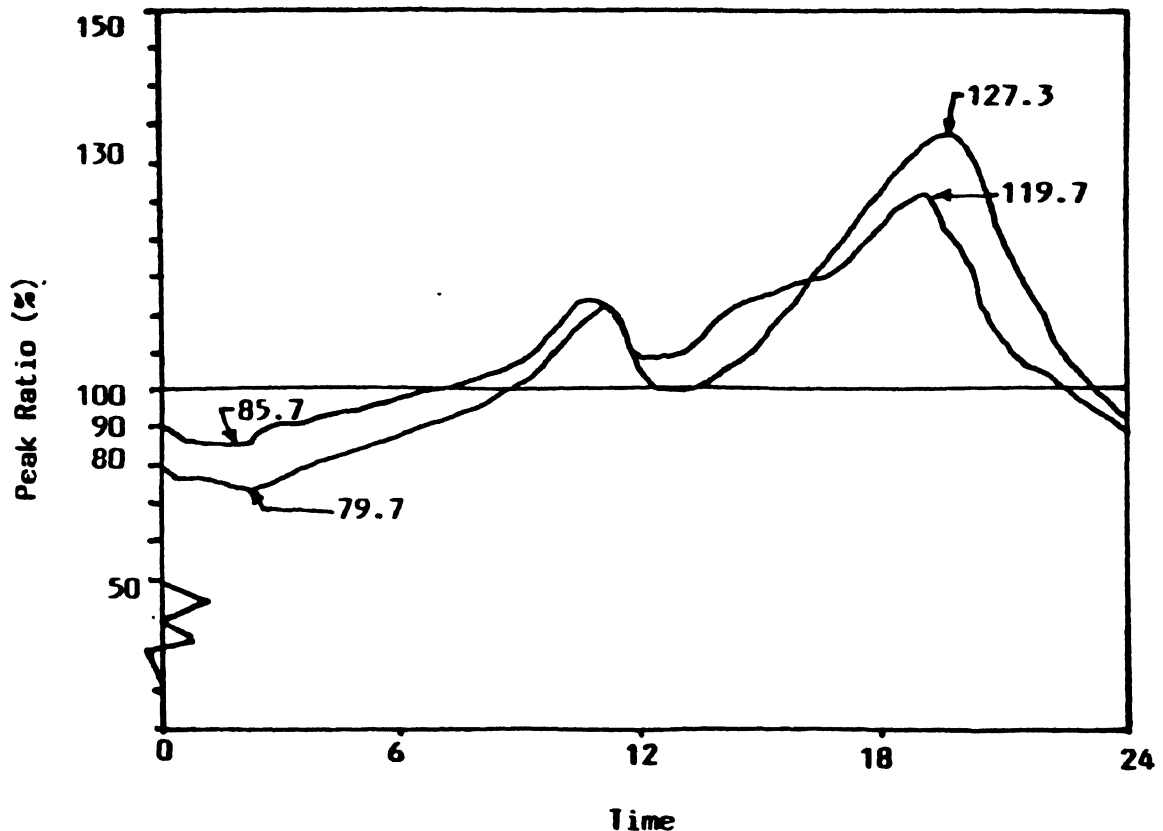


Fig. 2: Savings from peak load pricing - Korean experience

It will be seen that the peak ratio (ratio of peak-load to average load) reduced from 127.3 to 119.7, whereas the off-peak ratio increased from 79.5 to 85.7. A likely saving of US \$ 250 million in the new investment has been estimated by KEPCO, as a result of peak-load pricing (11).

THE INDIAN SCENE: SOME BACKGROUND INFORMATION

Some features of the power scene in India have a bearing on the application of a TOU pricing systems, and will be discussed in this section. Though the State Electricity Boards (SEBs) control nearly 80 per cent of the total generation, transmission and distribution in the country, the region has a special significance in Indian power planning. The country is divided into five regions - northern, western, southern, eastern and north-eastern - each region consisting of several states. In principle, investment planning is aimed at optimising regional operations, the implicit assumption being that there is unimpeded flow of power between states in a particular region. In actual practice, however, inter-state flows of power have been anything but smooth, and no region functions as one integrated system for any reasonable period.

Nevertheless, regional optimisation remains the stated basis of power planning in India. The relevance of this objective becomes evident when the question is raised - what is the peak that has to be tackled and flattened (if possible), by pricing? Is it the regional peak or the peak of the state concerned?

The problems involved in tackling the regional peak, by pricing or other methods of load management, require some discussion. Each SEB is a separate power

system, technically as well as financially. While there is a loose-knit association of SEBs in each region known as the Regional Electricity Board (REB), it does not have an organisational or legal identity of its own. In fact, each SEB has its own separate cost & tariff structure. While there is a continuing effort on the part of the central government (through its agencies such as the CEA, the Planning Commission, etc.) to optimise investment planning from the regional point of view, there are innumerable deviations from the regional approach in actual practice in planning as well as operations (for a description of the planning process and recent optimisation results, see Ref. 12). Regional optimisation implies that location of new projects in a particular state will be decided on the basis of the economics of feasible new projects in the entire region; for example, it may well turn out that a new project will be established in a state with surplus power availability, if it forms part of a regional optimal (least cost) plan to meet the power needs of all the states in the region. Needless to say, such an optimal plan will consider inter-state transmission costs also.

There are too many deviations from a regionally optimal operating system for us to be able to claim that flattening of the regional load curve will have much operational or economic significance. Each state electricity board is also an independent cost centre,

with its separate financial and tariff structure. It therefore, appears that the relevant peak to be flattened should be the state, and not the regional, peak.

SOME OBSERVATIONS ON POSSIBLE CONSUMER CATEGORY OF APPLICATION IN INDIA

In the application of time-of-use pricing, considerable metering and other administrative costs are involved. Special types of meters are needed to record kW demand and kWh consumption during specified hours of the day. These meters cost substantially higher than the usual energy meters used for consumers who have a time-uniform rate. Obviously, there is a trade-off involved in the selection of the consumer category to whom TOU pricing can be applied; the costs of metering (and allied expenses) have to be weighed against the (expected) benefits of TOU pricing by way of reduced peak demand of the system. The experience of the pioneers in TOU pricing has shown that it can be gainfully applied to large industrial consumers; this is so for two reasons: Firstly, metering and associated costs of TOU pricing are likely to be a small proportion of the total electricity bill of the consumer concerned; and secondly, there is a greater possibility of shifting consumption from peak to off-peak hours in the case of industrial consumers than in the case of other categories especially domestic/commercial consumers.^b In a subsequent section, we shall

illustrate these points by reference to an Indian electric utility.

TOU PRICING : POTENTIAL IN INDIA

We have already mentioned that the peak problem to be tackled by TOU pricing, is that of the future or potential peak. The question to be decided first is whether there is indeed a peak problem in Indian utilities. While many of our observations will relate to Indian utilities in general, the example of Tamil Nadu will be taken to illustrate the issues with reference to the load curves etc. of that system. An analysis can be extended to any other utility, though it is essential to tackle the peak problem on a case-to-case basis.

Figure 3 shows the load curve of the TNEB system for the second quarter of 1986. This load curve is the average of the three highest load curves in the quarter. Below this load curve, in the same figure, we have shown a typical load curve for HT industry in Tamil Nadu. This load curve is taken from a sample of industries surveyed in an on-going study by the Tata Energy Research Institute. The differences in the scales of the two load curves may be noted. HT industry in Tamil Nadu accounts for 37% of the total energy consumption (and perhaps more than 25% of the system peak demand); savings achieved during the peak hours by this category,

Fig.3 TNEB system load curve

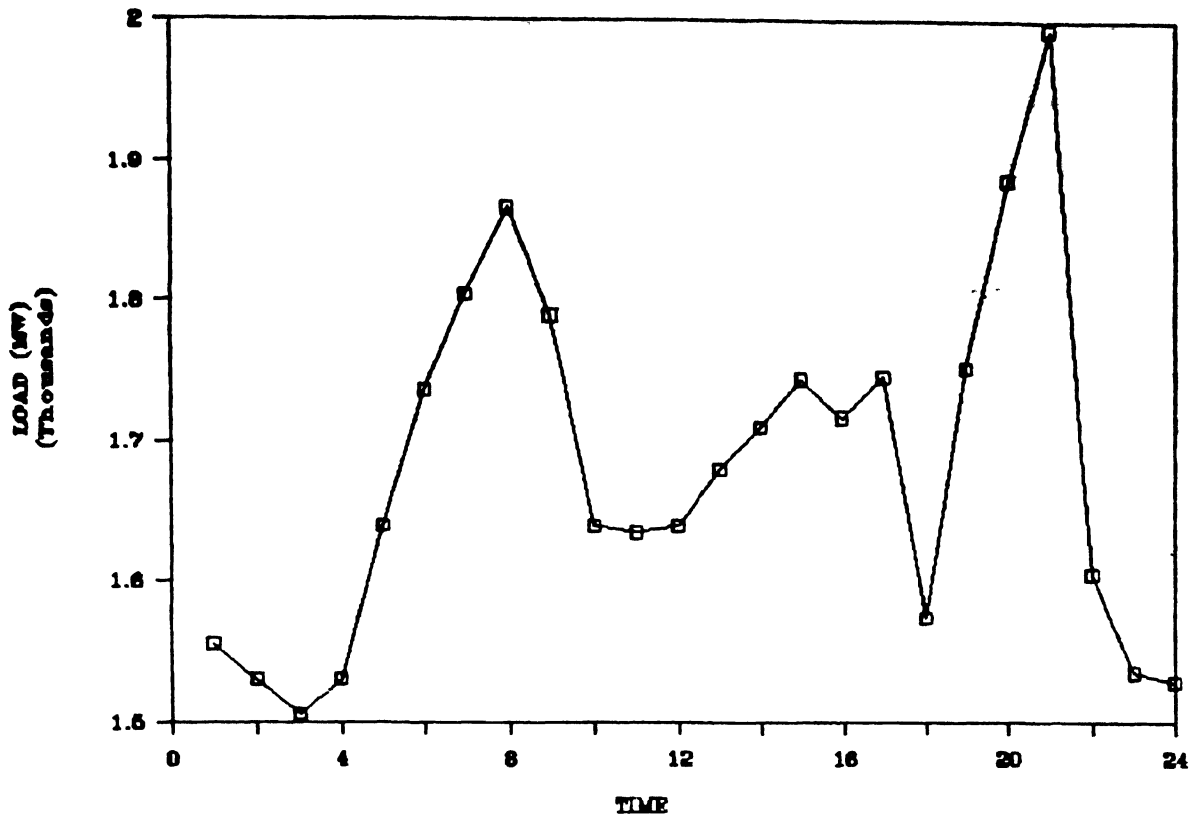
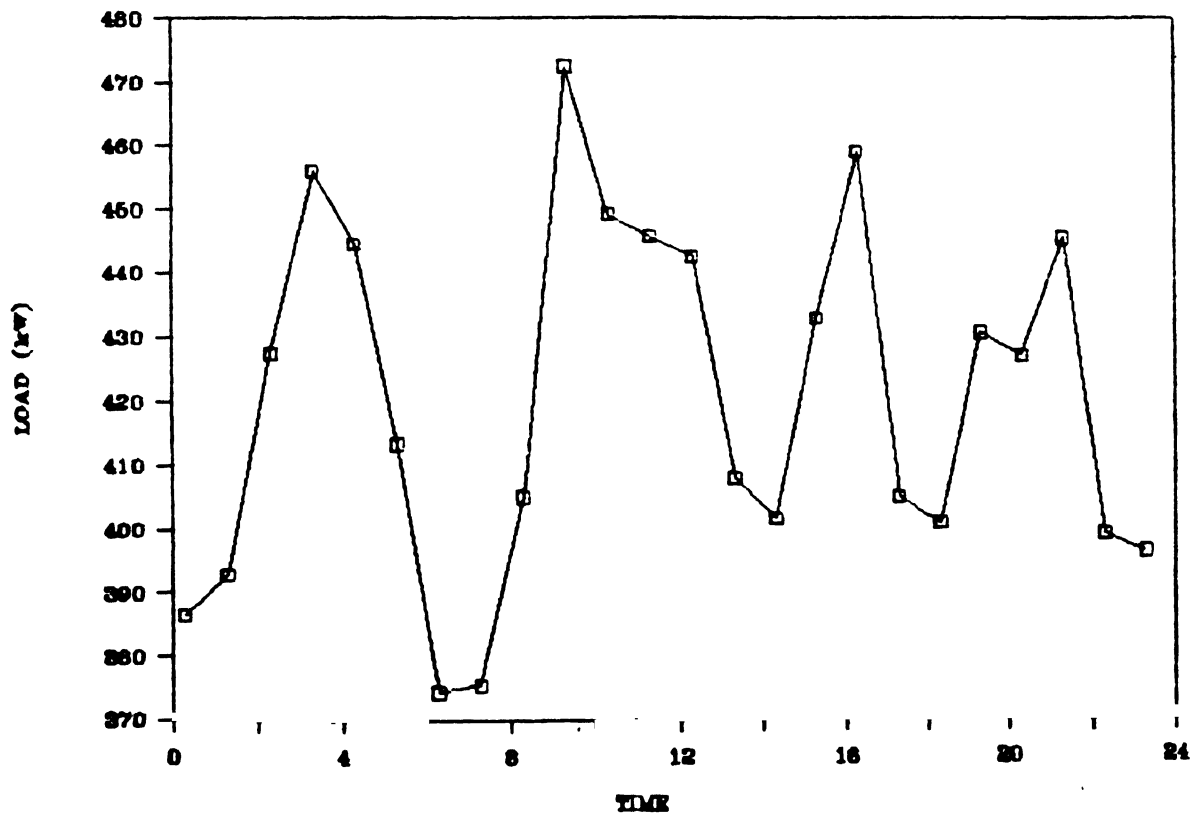


Fig.4 Sample load curve for HT industries



will obviously help the system substantially. If a part or the whole of this group is subjected to peak-load pricing, the likely benefits can be considerable. It will be noticed that both the morning and the evening peaks have some similarities in the two load curves. If, therefore, the peaks during these periods are flattened in the industrial load curve and the valleys are partially filled by shifting peak period consumption by an appropriate peak load pricing tariff, the system peaks will also be flattened to a significant extent.

The above brief description only indicates the probable benefits for the power system, resulting from peak load pricing for HT industry. Actually, there are innumerable problems to be solved before the potential savings from peak load pricing can be realised in practice. The most important problem is that of power cuts and load sheddings. Obviously, if H T industrial consumers (or a part of them) are subjected to a peak load pricing tariff, power cuts cannot be imposed on them during peak hours as is the current practice. The implication of peak load pricing, ofcourse, is that load management is sought to be implemented by pricing and not by physical rationing. If the peak-load tariff is properly designed, with a sufficiently steep disincentive for peak period consumption, combined with a sufficiently attractive concession for off-peak

consumption, it is likely that the peak period power shortages may be reduced because of shift of energy consumption from peak to off-peak hours. Other consumer categories may also have less cause to object if the H T tariff is suitably revised to reflect marginal costs during peak and off-peak hours. In effect, the industry will be paying more for greater reliability, and more importantly, benefitting the system.

The total cost to industry and the economy may well be lower because industry will probably have less recourse to captive generation in such a situation of greater assurance of supply.

THE NECESSITY FOR TARIFF 'EXPERIMENTS'

One of the main difficulties in designing a proper cost-based electricity tariff is the absence of reliable data regarding the demand side. The information gap is even more serious in regard to price-elasticities in the present situation, as we need to know the responsiveness of demand to price changes between periods i.e. inter-period price elasticities. While precise estimations of inter-period elasticity may be difficult or even impossible, an approximate estimate of the responsiveness of energy consumption to price changes in different periods can be obtained by properly designed tariff experiments. Such experiments

have been conducted in several developed countries mainly with a view to studying price elasticity, one of the better known experiments being the British tariff experiments conducted in the early 70s. Such experiments usually consist of an optional tariff given to the consumer category in order to study the varying responses of consumers opting for the revised tariff as against those continuing on the old tariff.

Alternatively, the Korean approach of a fairly long (18 months in Korea) preparatory period during which information is collected from a sample of HT industry consumers, may be followed. In the Indian situation perhaps we may initiate a data collection "pilot project" by the installation of sample meters which can record hour-to-hour consumption (including maximum demand) of these consumers for certain time period.

It is possible, for instance, to fix such meters in fifty or so establishments by rotation, shifting them to another group after a prescribed period of three to six months. While the details of the experiment need to be worked out after careful discussions with industries and utility representatives, such information collected over a period of two years or so, can be used to design an appropriate peak load pricing tariff for HT industrial consumers, which can then be either tried as an optional tariff, or introduced in respect of the

category. The important thing is to introduce this tariff after a detailed study has been made as proposed, as an improperly designed tariff introduced in haste will have negative long-term consequences.

FOOTNOTES

- a) A detailed discussion of the principles of marginal cost, pricing in electricity, lies outside the purview of this paper. Interested readers may please see Ref.1.
- b) It must be mentioned here that optional time-of-day tariffs for large domestic consumers, are also being initiated in some developed countries with mixed results.

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